Chapter 8

BURIED STRUCTURES

Curtis Bridge, Augusta

Twin # 2 Bridge, Farmington

8 BURIED STRUCTURES

8.1 General

8.1.1 Design

A buried structure should be considered for any relatively short span crossing, if such a structure is hydraulically adequate for the site. These bridges or minor spans may be full culverts with a bottom or three sided structures founded on footings. The presence of bedrock, environmental impact concerns, or fish passage issues may preclude the use of a buried structure with a bottom.

All metal buried structures in tidal waters should be aluminum. In inland waters, steel is preferred due to lower initial cost, although aluminum should be used if the existing steel structure is being replaced after less than 50 years of service.

The invert for all culvert-type structures should normally be located at 12 inches below estimated normal streambed to accommodate fish passage. Reducing this depth to 6 inches below streambed may be considered with involvement from the Environmental Coordinator. Reducing the depth below streambed should only be considered when there are conflicts with utilities or bedrock. The material used inside the buried structure should be excavated native streambed with cost incidental to installation. The placement of the structure should follow the slope of the streambed when possible.

Backfill material should be Granular Borrow meeting the requirements of Subsection 703.19, Material for Underwater Backfill. Structural Excavation is considered incidental to the structural plate structure as stated in the Standard Specifications, while Granular Borrow is paid for separately.

Guardrail treatment for buried structures with shallow cover is shown in Standard Detail 606 (24).

The minimum cover should be checked at the face of guardrail from the top of the bituminous pavement. Refer to the design section for the structure type of interest for minimum cover requirements. On local roads, minimum cover requirements may be reduced to the amount specified by the manufacturer when warranted.

8.1.2 Construction Practices

Steel or aluminum structural plate structures should be constructed in the dry for the following reasons:

- o They are designed to interact with the surrounding soil, which offers structural support and load-carrying capacity. Therefore, it is important that the bedding material and the material within the backfill limits be sufficiently and uniformly compacted so that this soil-structure interaction will occur. This is especially true for pipe arches and metal boxes because it is important for the bedding material to accommodate the high corner pressures that develop in the structure.

- o Environmental concerns such as fish passage and erosion control require that the stream flow be maintained and that the stream be properly protected against siltation.

- o Saturated backfill could result in unbalanced buoyant forces.

To achieve dry construction conditions, a cofferdam should be used for the installation of all buried structures. For culvert-type structures, two cofferdam pay items should be added to the list of quantities, one for the upsteam end and one for the downstream end. Three-sided structures will also need two cofferdams, one for each footing.

In some cases where 3 feet or more of ponded water exists, it may be acceptable to install structural plate pipes and pipe arches in the wet due to the environmental impacts of installing large cofferdams. However, these projects will be handled on a project-by-project basis, and will require close coordination with the regulating environmental agencies and the Construction Resident for approval of the installation procedures. Construction of metal box structures and pipe arches with 4 tsf corner pressure will always require a cofferdam.

Standard Specification Section 509 – Structural Plate Pipes, Pipe Arches, Arches, and Metals Box Culverts describes requirements for lift thickness and balanced lift placement. However, construction requirements controlling compaction of the soil envelope and bedding material are not currently in the Standard Specifications, so compaction requirements must be specified by a special provision or a note on the plans. See the Geotechnical Designer for the appropriate compaction specification.

8.2 Structural Plate Pipes and Pipe Arches

8.2.1 Design

Pipe and pipe arch sizes are determined by hydraulic analysis utilizing the invert at estimated normal streambed. Pipe arches are then increased to the next larger size when inverts are placed at 6 inches below streambed or two sizes larger when placed at 12 inches below streambed to offset the loss of flow area. Round pipes are increased one size larger for both 6 inch and 12 inch placements of inverts below streambed.

Structural plate pipe arches should be selected for a maximum corner pressure of 2 tsf wherever possible. If a corner pressure of 4 tsf is necessary to select a pipe arch, refer to Section 8.2.3 Soil Envelope.

The lengths of pipes and pipe arches along bottom centerline of structure are specified in intervals of 2 feet. Span and rise dimensions are specified to the nearest 1-1/2".

The minimum cover required is the span divided by 8 or 1'-6" minimum, whichever is greater.

8.2.2 Foundation Preparation

The bearing capacity of the foundation/backfill soils at the structure corners must be adequate to carry the design corner bearing pressure. Minimum excavation and underwater backfill bedding limits, regardless of the subgrade material, are shown in Figure 8-1.

In general, the foundation must provide uniform support for the pipe invert. Boulders, rocks, and/or soft spots must be excavated and voids backfilled with compacted underwater backfill material.

It is desirable for metal pipes and arches to bear on a relatively unyielding or fixed foundation as compared to the adjacent backfill. Otherwise, differential settlement between the soil envelope and the structure could create downdrag forces on the sidewalls of the pipe or arch. Uniform settlement along the length of the pipe is also desirable.

8.2.2.1 Bedrock

It is undesirable for metal pipes and pipe arches to bear directly on bedrock due to localized contact stresses. If bedrock is expected to be present at the bearing elevation, subgrade preparation may include:

- Removal of 1 foot minimum of bedrock and replacement with compacted underwater backfill material. The excavation should extend laterally 1 foot minimum beyond the proposed footprint of the pipe.

- Reshaping of the bedrock into a shallow v-shaped cradle in which to set the pipe.

- Placing the pipe on a smooth bedrock surface and placing flowable fill to provide even support in the haunch zone. This approach is the least desirable.

8.2.2.2 Soft Soils

Where poor or soft soils are encountered, consideration should be given to removing some or all of the poor material and replacing it with compacted underwater backfill material. A separation geotextile may be required to prevent mixing and migration of the underwater backfill material into the underlying poor soils.

For soils where a 1 foot thick bed will not support the design corner pressure, the bearing capacity of the foundation soil will need to be improved by removal of 2 feet of soft subgrade soil and replacement with compacted underwater backfill material and/or the use of a stabilization/reinforcement geotextile.

The structural backfill soil envelope should not settle more than the pipe, in order to avoid potential downdrag loads on the pipe. Therefore, any layer of stabilization/reinforcement geotextile should extend at least 1 foot beyond the pipe and into the soil backfill envelope.

8.2.3 Soil Envelope

The bearing material around the corners of the pipe and pipe arch must be capable of supporting the design corner pressure. The lateral limits of the pipe/pipe arch soil envelope are shown in Figure 8-1 and Figure 8-2. For structures with a corner pressure of 4 tsf, backfill limits should be increased to 1/2 span plus 6 feet each side.

For adequate compaction between pipes, the spacing of multiple pipes or pipe arches must be greater than 1/2 span or 3.0 feet, whichever is less. Structures backfilled with flowable fill will need to be restrained against flotation.

Structure backfill material and compaction requirements should be provided by the Geotechnical Designer for inclusion in the contract documents.

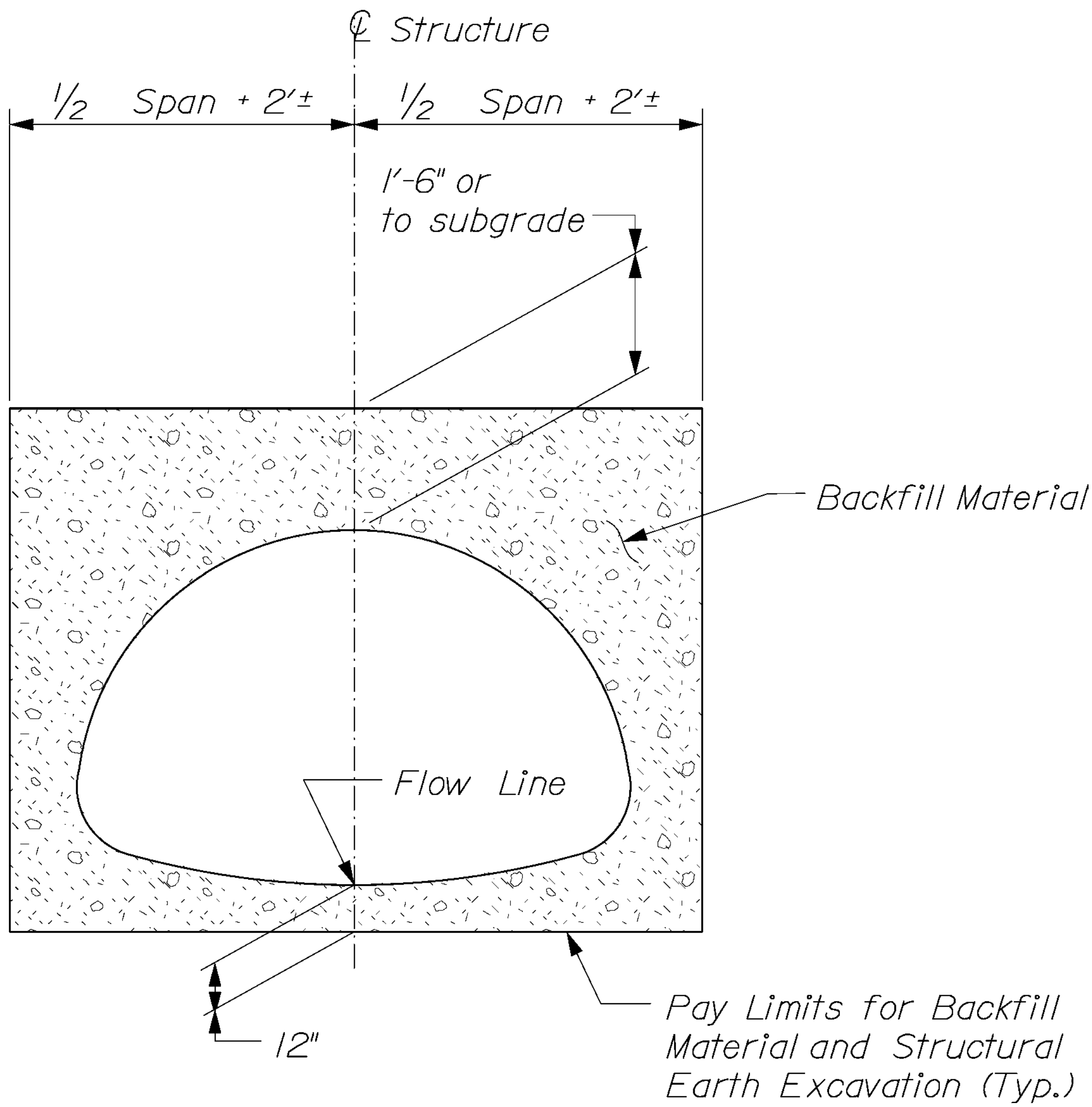


Figure 8-1 Excavation and Backfill Limits for Pipe or Pipe Arch Structures

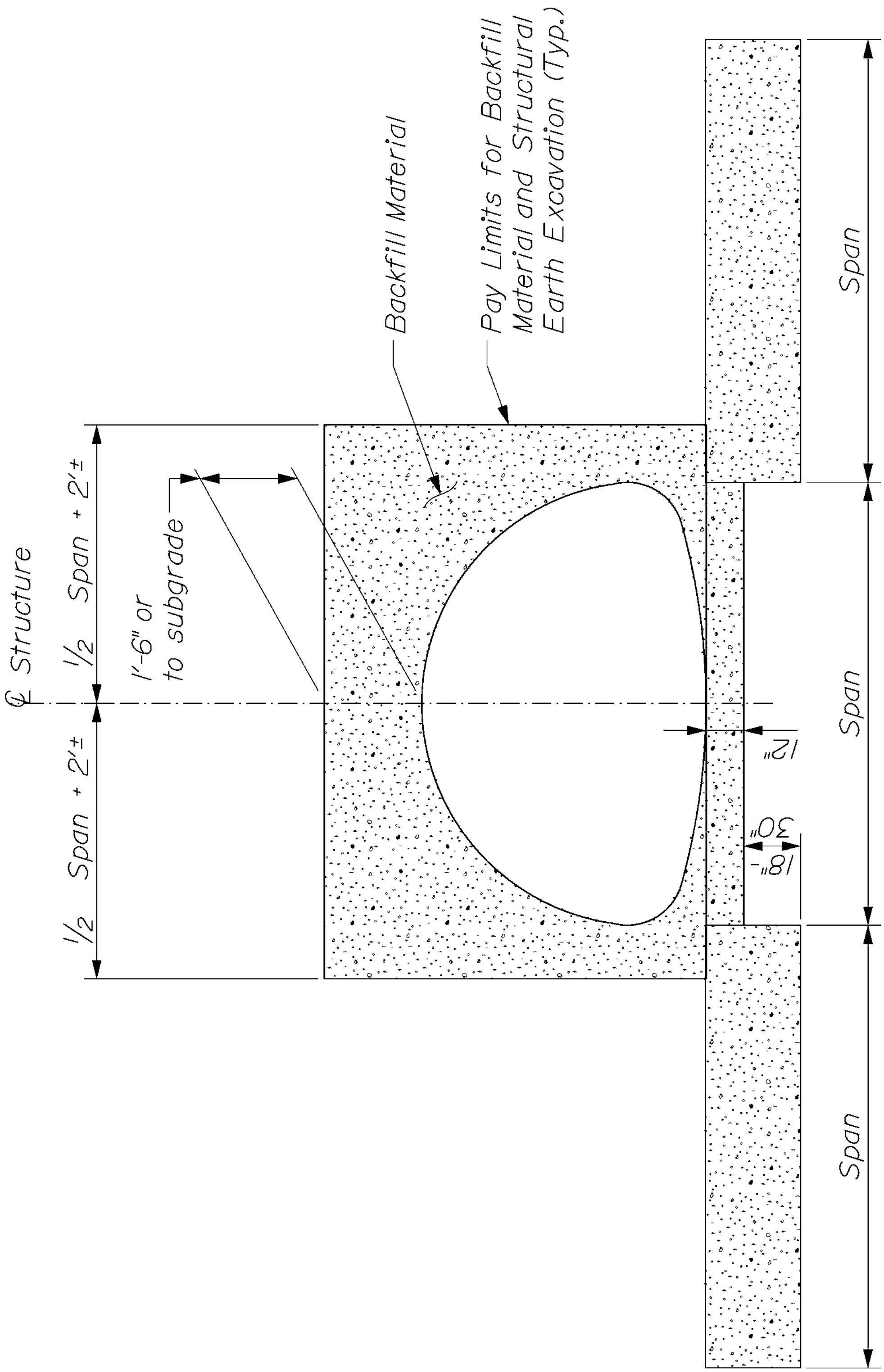


Figure 8-2 Excavation and Backfill Limits for Pipe or Pipe Arch Structures - Soft Soils

8.2.4 Structural Plate Pipes and Pipe Arches Design Tables

These tables specify structural plate thickness requirements for a given structure size, corner radius, and corner radius pressure up to a maximum fill height of 30 feet. Additional metal thickness to resist abrasion and corrosion has been included in these tables.

All steel plates below ordinary high water should be specified two available plate thicknesses heavier than those shown in the tables. In stream crossings where corrosion or abrasion is known to be severe on metal pipes, consideration should be given to providing further increases in thickness over that indicated in the tables.

The plate thickness for aluminum structural plate structures should be specified on the contract documents as shown in the tables. If reinforcing ribs are required for the structure, they should be designed by the manufacturer. The thickness of the plates for design should be the thickness stated on the plans minus 0.055 inches. Refer to Appendix D Standard Notes.

Commentary: Some readily available structural plate pipe and pipe arch sizes have changed from those listed in the 1996 Bridge Design Manual, and are reflected in the tables in this Guide. It should be noted however, that all previously available sizes could be obtained if needed for an extension of an existing structure.

A computer program was developed to design all available structural plate pipes based on AASHTO Design Criteria according to Section 9 of AASHTO 1977 Specifications through interims 1981. Pipe tables were developed along with the computer program to provide a documented design and detail guide for structural plate pipes, pipe arches, and plate arches. The design criteria for this analysis are as follows:

Live Load = HS25
Weight of Earth = 125 pcf
Soil Modulus (E') = 1050 psi
Compaction = 85% Standard Density (AASHTO T99)
Safety Factor for Wall Buckling = 2 for pipes and pipe arches, 4 for plate arches
Bolts (aluminum and steel pipes) = Galvanized Steel

The metal thickness shown in the steel pipe tables was derived by providing an additional 0.060” to the minimum design requirements, from the computer input, and rounding up to the nearest available plate thickness. This provides a reserve thickness for abrasion and corrosion losses in addition to the added thickness for plates below ordinary high water.

The metal thickness shown in the aluminum pipe tables was derived by providing an additional 0.055” to the minimum design requirements, from the computer output, and rounding up to the nearest available plate thickness. This provides a reserve thickness for abrasion and corrosion losses and provides additional stiffness for handling.

Documentation of all design data is located in the Bridge Program Library Research Files. These pipe tables apply to highway fills above the top of pipes up to 30 feet in depth, though computer output data is available for higher fill depths. Plate thickness for fill heights greater than 30 feet must be approved by the Engineer of Design.

Table 8-1 Structural Steel Plate Pipes

Pipe Diameter (in)	Area (ft^2)	Min. Cover (ft)	Maximum Fill Height Above Top of Pipe (feet) Metal Thickness in inches					
			0.138 in	0.168 in	0.188 in	0.218 in	0.249 in	0.280 in
60	20	1.5	20	30	30	30	30	30
66	24	1.5	20	30	30	30	30	30
72	28	1.5	18	30	30	30	30	30
78	33	1.5	16	30	30	30	30	30
84	38	1.5	16	30	30	30	30	30
90	44	1.5	14	25	30	30	30	30
96	50	1.5	14	25	30	30	30	30
102	57	1.5	12	25	30	30	30	30
108	64	1.5	12	20	30	30	30	30
114	71	1.5	12	20	30	30	30	30
120	78	1.5	11	20	25	30	30	30
126	87	1.5	10	20	25	30	30	30
132	95	1.5	9	20	25	30	30	30
138	104	1.5	9	18	25	30	30	30
144	113	1.5	8	18	20	30	30	30
150	123	1.6	8	16	20	30	30	30
156	133	1.6	7	16	20	30	30	30
162	143	1.7		16	20	25	30	30
168	154	1.8		14	20	25	30	30
174	165	1.8		14	20	25	30	30
180	177	1.9		14	18	25	30	30
186	189	1.9		12	18	25	30	30
192	201	2.0			18	20	30	30
198	214	2.1			16	20	30	30
204	227	2.1			16	20	30	30
210	241	2.2				20	25	30
216	254	2.3				20	25	30
222	269	2.3				20	25	30
228	284	2.4				20	25	30
234*	299	2.4					25	30
240*	314	2.5					25	30
246*	330	2.6					20	25
252*	346	2.6					20	25

* These pipes are not fabricated with available thicknesses to allow increasing bottom plates by 2 available sizes. Their use shall be only as approved by the Engineer of Design.

Table 8-2 Steel Structural Plate Pipe Arches

18 inch Corner Radius

Size Span x Rise	Area (ft^2)	Min. Cover (ft)	Max. Fill Height Above Top of Pipe Arch (feet) For Indicated Design Corner Pressure in tons/ft^2 Metal Thickness in Inches			
			0.138 in		0.168 in	
			2 tsf	4 tsf	2 tsf	4 tsf
6'-1" x 4'-7"	22	1.5	14	18	14	30
6'-4" x 4'-9"	24	1.5	14	18	14	30
6'-9" x 4'-11"	26	1.5	14	16	14	25
7'-0" x 5'-1"	28	1.5	12	16	12	25
7'-3" x 5'-3"	31	1.5	12	14	12	25
7'-8" x 5'-5"	33	1.5	12	14	12	20
7'-11" x 5'-7"	35	1.5	12	14	12	20
8'-2" x 5'-9"	38	1.5	11	14	11	20
8'-7" x 5'-11"	40	1.5	11	12	11	20
8'-10" x 6'-1"	43	1.5	10	12	10	20
9'-4" x 6'-3"	46	1.5	10	12	10	20
9'-6" x 6'-5"	49	1.5	10	12	10	20
9'-9" x 6'-7"	52	1.5	9	11	9	18
10'-3" x 6'-9"	55	1.5	8	11	8	18
10'-8" x 6'-11"	58	1.5	7	10	7	16
10'-11" x 7'-1"	61	1.5	7	9	7	16
11'-5" x 7'-3"	64	1.5	6	9	6	16
11'-7" x 7'-5"	67	1.5	6	9	6	16
11'-10" x 7'-7"	71	1.5	6	8	6	16
12'-4" x 7'-9"	74	1.5	6	8	6	14
12'-6" x 7'-11"	78	1.6	6	8	6	14
12'-8" x 8'-1"	81	1.6	6	8	6	14
12'-10" x 8'-4"	85	1.6	6	7	6	14

In general, use 2 tsf design corner pressure. For 4 tsf design corner pressure, refer to Section 8.1.1 Design.

Table 8-3 Steel Structural Plate Pipe Arches

31 inch Corner Radius

Size Span x Rise	Area (ft^2)	Min. Cover (ft)	Max. Fill Height Above Top of Pipe Arch (feet) For Indicated Design Corner Pressure in tons/ft^2 Metal Thickness in inches							
			0.138 in		0.168 in		0.188 in		0.218 in	
			2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf
13'-3"x 9'-4"	98	1.7	7	7	11	16	11	20	11	20
13'-6"x 9'-6"	102	1.7	7	7	11	16	11	20	11	20
14'-0"x 9'-8"	106	1.8	6	6	11	14	11	20	11	20
14'-2"x 9'-10"	110	1.8	6	6	11	14	11	20	11	20
14'-5"x 10'-0"	115	1.8	6	6	11	14	11	20	11	20
14'-11"x 10'-2"	119	1.9	6	6	10	14	10	18	10	20
15'-4"x 10'-4"	124	1.9	6	6	10	14	10	18	10	20
15'-7"x 10'-6"	129	1.9	6	6	9	12	9	18	9	20
15'-10"x 10'-8"	133	2.0	6	6	9	12	9	18	9	20
16'-3"x 10'-10"	138	2.0	5	5	9	12	9	16	9	20
16'-6"x 11-0"	143	2.1			9	12	9	16	9	20
17'-0"x 11'-2"	148	2.1			8	12	8	16	8	18
17'-2"x 11'-4"	153	2.1			8	12	8	16	8	18
17'-5"x 11'-6"	158	2.2			8	12	8	16	8	18
17'-11"x 11'-8"	163	2.2			8	11	8	14	8	18
18'-1"x 11'-10"	168	2.3			8	11	8	14	8	18
18'-7"x 12'-0"	174	2.3			8	11	8	14	8	16
18'-9"x 12'-2"	179	2.3			7	11	7	14	7	16
19'-3"x 12'-4"	185	2.4			7	10	7	14	7	16
19'-6"x 12'-6"	191	2.4					7	14	7	16
19'-8"x 12'-8"	196	2.5					7	14	7	16
19'-11"x 12'-10"	202	2.5					7	14	7	16
20'-5"x 13'-0"	206	2.6					7	12	7	14
20'-7"x 13'-2"	214	2.6					7	12	7	14

In general, use 2 tsf design corner pressure. For 4 tsf design corner pressure, refer to Section 8.1.1 Design.

Table 8-4 Aluminum Structural Plate Pipes

Pipe Diameter (in)	Area (ft^2)	Min. Cover (ft)	Maximum Fill Height Above Top of Pipe (feet) Metal Thickness in inches				
			0.150 in	0.175 in	0.200 in	0.225 in	0.250 in
60	20	1.5	25	30	30	30	30
66	24	1.5	20	30	30	30	30
72	28	1.5	20	30	30	30	30
78	33	1.5	20	30	30	30	30
84	38	1.5	18	25	30	30	30
90	44	1.5	18	25	30	30	30
96	50	1.5	16	25	30	30	30
102	57	1.5	14	20	30	30	30
108	64	1.5	14	20	30	30	30
114	71	1.5	14	20	25	30	30
120	78	1.5	12	20	25	30	30
126	87	1.5	12	18	25	30	30
132	95	1.5	12	18	20	30	30
138	104	1.5	11	16	20	25	30
144	113	1.5	10	16	20	25	30
150	123	1.6		16	20	25	30
156	133	1.6		14	20	25	25
162	143	1.7		14	20	20	25
168	154	1.8			18	20	25
174	165	1.8			18	20	25
180	177	1.9			18	20	25
186	189	1.9				20	20
192	201	2.0				20	20
198	214	2.1				20	20
204	227	2.1					20
210	241	2.2					20
216*	254	2.3					20
222*	269	2.3					20
228*	284	2.4					20
234*	299	2.4					20
240*	314	2.5					20

* These pipes do not have the reserve thickness provisions as the other pipes. Their use will be only as approved by the Engineer of Design.

Table 8-5 Aluminum Structural Plate Pipe Arches

Size Span x Rise	Area (ft^2)	Min. Cover (ft)	Maximum Fill Height Above Top of Pipe Arch (feet) For Indicated Corner Pressure in tons/ft^2 Metal Thickness in inches									
			0.150 in		0.175 in		0.200 in		0.225 in		0.250 in	
			2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf
6'-7" x 5'-8"	30	1.5	20	20	20	30	20	30	20	30	20	30
6'-11" x 5'-9"	32	1.5	18	18	20	25	20	30	20	30	20	30
7'-3" x 5'-11"	34	1.5	18	18	20	25	20	30	20	30	20	30
7'-9" x 6'-0"	37	1.5	16	16	18	25	18	30	18	30	18	20
8'-1" x 6'-1"	39	1.5	16	16	18	25	18	30	18	30	18	30
8'-5" x 6'-3"	42	1.5	16	16	18	20	18	30	18	30	18	30
8'-10" x 6'-4"	44	1.5	14	14	16	20	16	30	16	30	16	30
9'-3" x 6'-5"	47	1.5	14	14	14	20	14	25	14	30	14	30
9'-7" x 6'-6"	50	1.5	14	14	14	20	14	25	14	30	14	30
9'-11" x 6'-8"	53	1.5	12	12	14	20	14	25	14	30	14	30
10'-3" x 6'-9"	55	1.5	12	12	14	20	14	25	14	25	14	30
10'-9" x 6'-10"	58	1.5	12	12	12	18	12	25	12	25	12	25
11'-1" x 7'-0"	61	1.5	12	12	12	18	12	20	12	25	12	25
11'-5" x 7'-1"	64	1.5	11	11	12	16	12	20	12	25	12	25
11'-9" x 7'-2"	67	1.5	10	10	12	16	12	20	12	25	12	25
12'-3" x 7'-3"	70	1.5	10	10	10	16	10	20	10	20	10	20
12'-7" x 7'-5"	74	1.6	9	9	10	16	10	20	10	20	10	20
12'-11" x 7'-6"	77	1.6	9	9	10	14	10	20	10	20	10	20
13'-1" x 8'-2"	83	1.6	9	9	10	14	10	20	10	20	10	20
13'-1" x 8'-4"	87	1.6	9	9	10	14	10	20	10	20	10	20
13'-11" x 8'-5"	90	1.7	8	8	9	14	9	20	9	20	9	20
14'-0" x 8'-7"	94	1.8	8	8	10	14	10	18	10	20	10	20
13'-11" x 9'-5"	101	1.7	8	8	11	14	11	18	11	20	11	20

(This table continues on the next page.)

Size Span x Rise	Area (ft^2)	Min. Cover (ft)	Maximum Fill Height Above Top of Pipe Arch (feet) For Indicated Corner Pressure in tons/ft^2 Metal Thickness in inches									
			0.150 in		0.175 in		0.200 in		0.225 in		0.250 in	
			2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf	2 tsf	4 tsf
14'-3" x 9'-7"	106	1.8	8	8	11	11	11	14	11	20	11	20
14'-8" x 9'-8"	110	1.8	8	8	10	11	10	14	10	20	10	20
14'-11" x 9'-10"	114	1.9			10	11	10	14	10	20	10	20
15'-4" x 10'-0"	119	1.9			10	11	10	14	10	20	10	20
15'-7" x 10'-2"	123	1.9			9	11	9	14	9	20	9	20
16'-1" x 10'-4"	128	2.0			9	11	9	14	9	20	9	20
16'-4" x 10'-6"	132	2.0			9	11	9	14	9	20	9	20
16'-9" x 10'-8"	137	2.1					8	14	8	18	8	18
17'-0" x 10'-10"	142	2.1					8	14	8	18	8	18
17'-3" x 11'-0"	147	2.2					8	14	8	18	8	18
17'-9" x 11'-2"	152	2.2					8	14	8	18	8	18
18'-0" x 11'-4"	157	2.3					8	14	8	18	8	18
18'-5" x 11'-6"	162	2.3							8	16	8	16
18'-8" x 11'-8"	167	2.3							8	16	8	16
19'-2" x 11'-9"	172	2.4							7	14	7	16
19'-5" x 11'-11"	178	2.4							7	14	7	16
19'-10" x 12'-1"	183	2.5									7	16
20'-1" x 12'-3"	188	2.5									7	14
20'-1" x 12'-6"	194	2.5									7	14
20'-10" x 12'-7"	200	2.6									7	14
21'-6" x 12'-11"*	211	2.7									6	12

(This table is continued from previous page.)

1. In general, use 2 tsf design corner pressure. For 4 tsf design corner pressure, refer to 8.1.1 Design.

2. The pipe arch indicated with an (*) does not have the reserve thickness provision as the other pipe arches. Its use will be only as approved by the Engineer of Design.

8.2.5 End Treatment

8.2.5.1 Steel Structural Plate Structures

All pipes and pipe arches should have end bevels cut on a 1.75:1 slope normal to the end skew as shown in Figure 8-3. A bottom step cut should be provided as recommended by the manufacturer. The embankment slopes above the pipe should be 2:1, but may be steepened to 1.75:1 when warranted. Embankment slopes steeper than 2:1 must be stabilized by a layer of riprap with a minimum thickness of 1 foot.

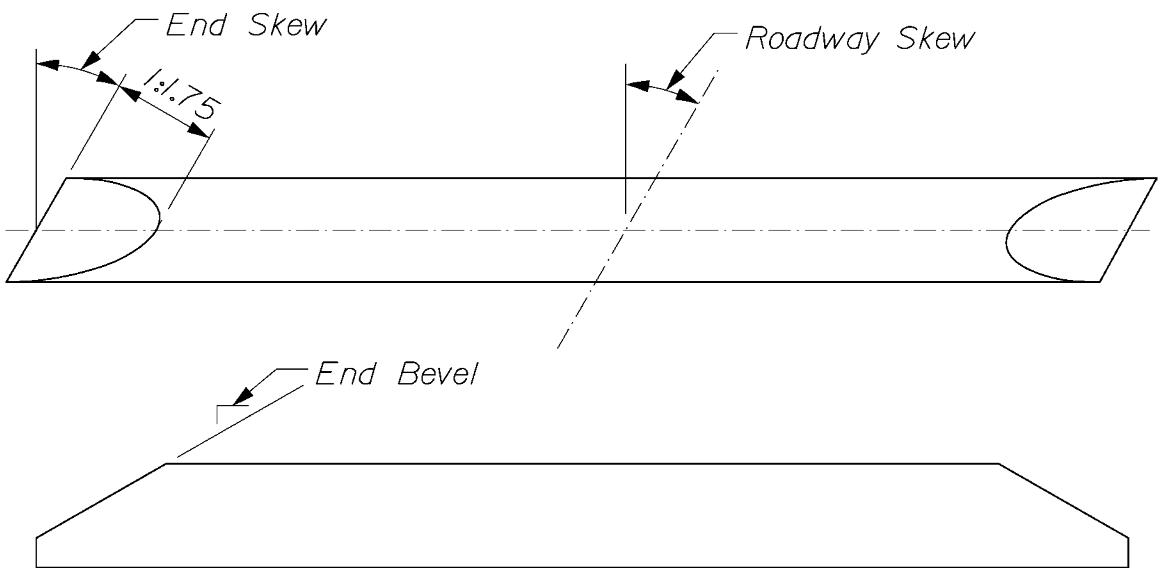


Figure 8-3 End Skews and Bevels for Pipe or Pipe Arch Structures

The treatment of the end skew will vary depending upon the roadway skew and the size of the structure. A pipe arch is considered "large" when the span is approximately 15 feet, and the rise is approximately 12 feet.

- o Roadway skew up to 15º:

  Small pipe, and/or deep cover over pipe - Ends should be cut square and the embankment slopes warped to fit the pipe.

  Large pipe with shallow cover over pipe - End skews should be provided to prevent warped slopes from being steeper than 1.5:1.

- o Roadway skew between 15º and 20º inclusive:

Small pipe - End skews should be provided to prevent warped slopes from being steeper than 1.5:1.

Large pipe - Same as for small pipe, but the end skew is limited to a maximum of 15º.

- o Roadway skew over 20º:

End skews should be provided giving consideration to the size of the structure and the amount of cover and to prevent warped slopes from being steeper than 1.5:1. End skew is limited to a maximum of 20º. In some cases, slight lengthening of the structure may be necessary to meet the above requirements.

8.2.5.2 Aluminum Structural Plate Structures

The end treatments described for steel structural plate structures also apply to aluminum pipes and pipe arches, except that the end skew should not exceed 15°. When used, the height of the bottom step cut should be approximately equal to 1/3 times the rise.

In addition, end reinforcement should be provided as shown in Figure 8-4 for all aluminum plate pipes and pipe arches with spans greater than 10 feet. Where end reinforcement is not required, a top step cut should be provided with a height equal to about half the bottom step for pipe arches.

End reinforcement devices must be composed of aluminum with sufficient strength to provide a minimum section modulus about an axis perpendicular to the center of the pipe of 1.10 in^3/ft of pipe circumference. Maximum spacing of the devices is 5'-5", with attachments using 3/4" diameter aluminum bolts. Section properties, details of the device, and the method of attachment must be submitted to the Resident for approval. Refer to Figure 8-4 and Appendix D Standard Notes Structural Plate Structures.

In areas where ice is common, particularly on coastal streams, an alternate end reinforcement design utilizing a concrete collar should be considered. Refer to Figure 8-5 and Figure 8-6 for further guidance. In these cases, a barrier must be placed between the aluminum and the concrete to prevent interaction.

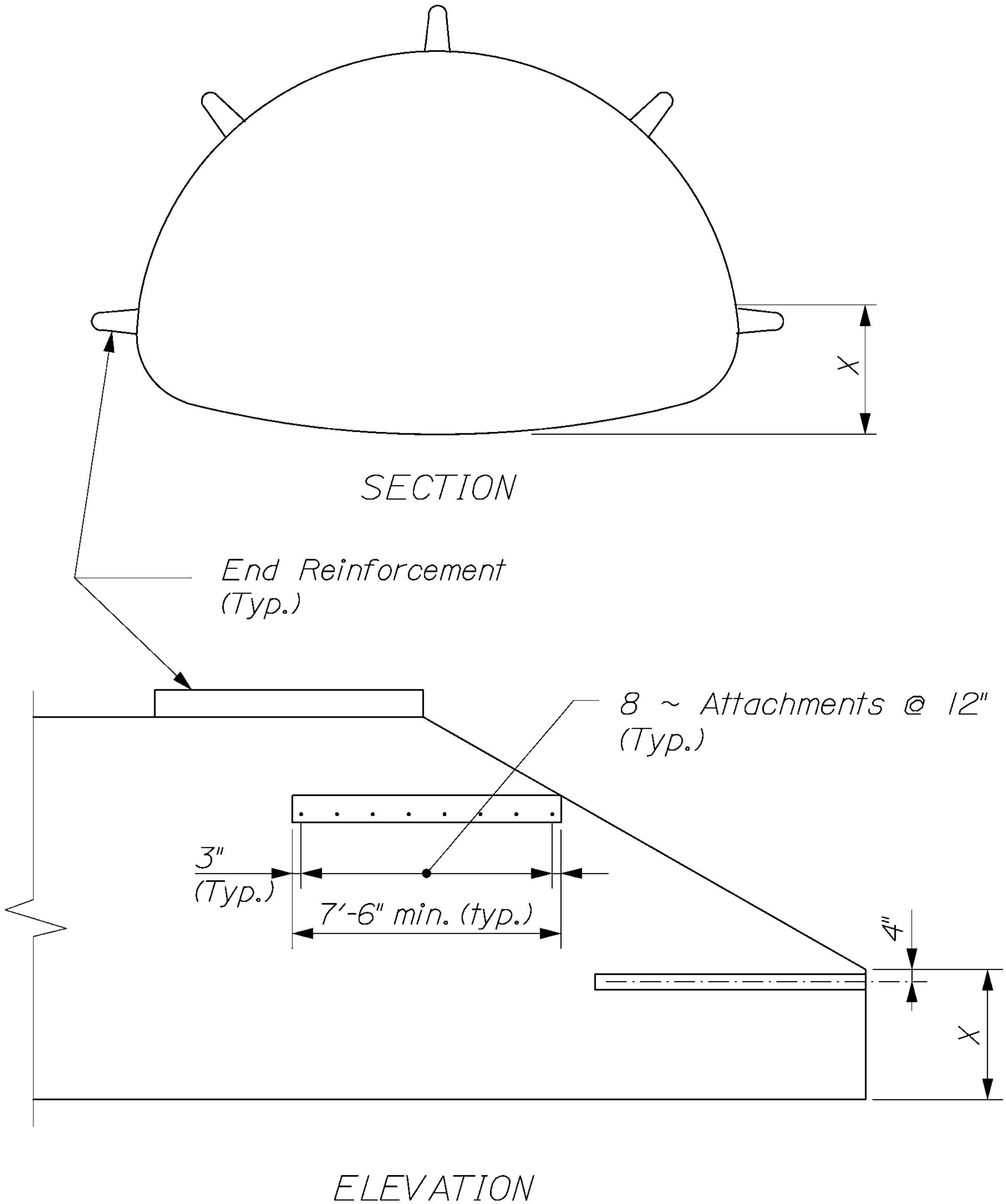
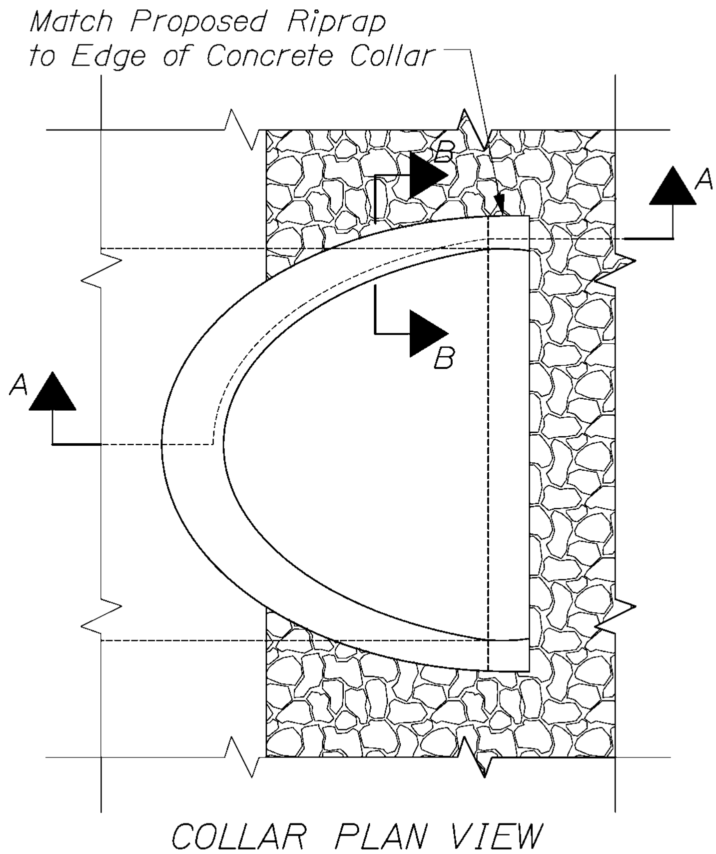


Figure 8-4 End Reinforcement of Aluminum Pipe or Pipe Arch Structures



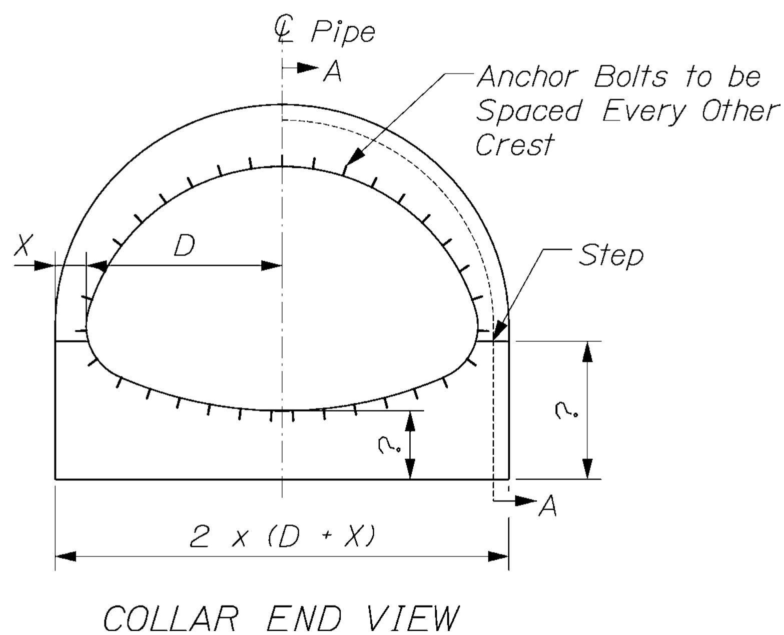
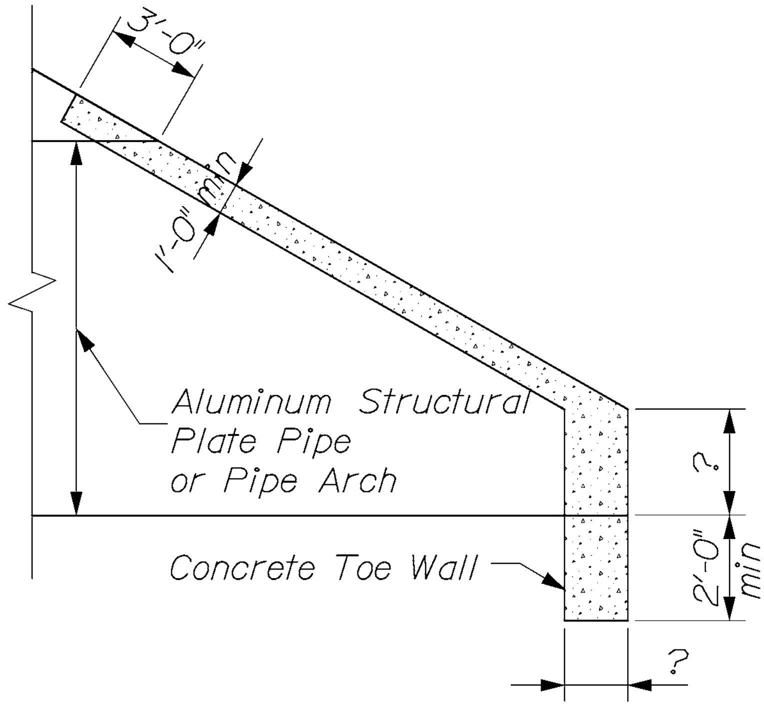
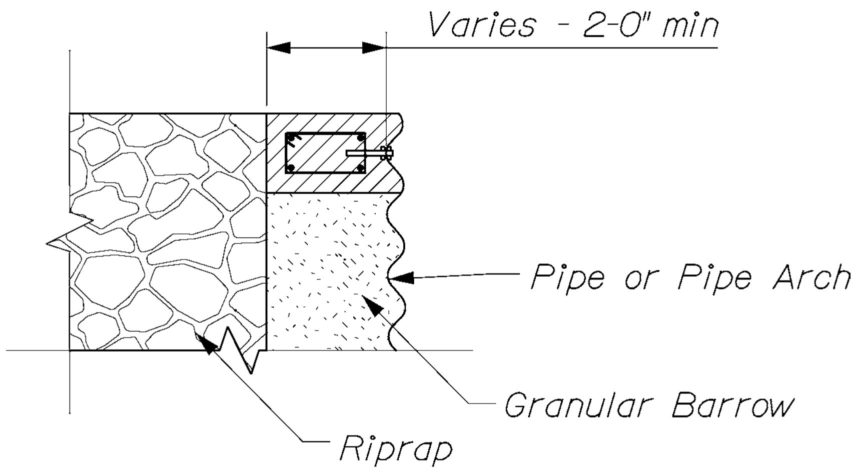


Figure 8-5 Concrete Collar for Aluminum Pipe or Pipe Arch Structures - Plan and End Views



SECTION A-A



SECTION B-B

Figure 8-6 Concrete Collar for Aluminum Pipe or Pipe Arch Structures, Section Views

8.3 Boxes

8.3.1 Design

Box structures discussed here will have a bottom plate or slab. For those without a bottom, refer to Section 8.4 Three-Sided Structures and Arches. Material may be precast concrete, cast-in-place concrete, or metal structural plate. All box structures should include toe walls at both ends to prevent undermining.

The Designer should specify HS25 loading and allow the manufacturer to design the box structure. Only the basic layout and required hydraulic opening is detailed, so the Contractor can choose among available proprietary products.

If possible, the structure length should be designed long enough to preclude the need for wingwalls, using beveled ends similar to those used for pipe projects. Also, the ends of the box should not be skewed; the length of the structure should be increased slightly and the sideslopes warped to accommodate the skew of the box to the roadway. If wingwalls are required, refer to Section 5.6.5 Prefabricated Proprietary Walls.

8.3.2 Metal Structural Plate Box Culvert (Steel or Aluminum)

Generally, an aluminum structural plate box culvert is preferred over steel due to the uncertainty of the long term durability of the steel frame, and the potential for catastrophic failure when deterioration occurs. Toe walls can be metal or concrete, and should have a minimum height of 2 feet.

The plate thickness of the headwalls, wingwalls, and invert plates, should be as recommended by the manufacturer. The shell plate thickness should equal the plate thickness recommended by the manufacturer plus 0.055 inches or 0.060 inches for aluminum or steel structures, respectively. If reinforcing ribs are required for the structure, they should be designed by the manufacturer. The thickness of the plates for design should be the thickness stated on the plans minus 0.055 inches or 0.060 inches for aluminum or steel structures, respectively. Refer to Appendix D Standard Notes Structural Plate Structures.

Follow the manufacturer’s recommendations in specifying length, which is usually in multiples of 4.5 feet to minimize structure costs. Use of headwalls will require further length restrictions, as discussed below.

When headwalls are used, the total structure length should be a multiple of 9 inches, and the headwall should be at least 3 feet away from the face of the guardrail. This clearance will reduce the risk of headwall damage if the guardrail is hit. For shallow cover situations, the length of the shell may need to be increased so that the anchor rod between the shell and the headwall avoids the concrete around the guardrail posts. The anchor rods supporting the headwalls cannot be embedded in concrete.

It is recommended that roads be paved over metal boxes whenever possible. The minimum cover described by the manufacturer should be increased by 6 inches for a gravel road.

8.3.2.1 Foundation Preparation and Backfill Envelope

Structural plate box culverts must be founded on a 12 inch minimum leveling course consisting of compacted structural backfill, conforming to granular borrow for underwater backfill. In general, the foundation must provide adequate and uniform support for the box bottom and bedding material. Boulders or rocks within the limits of required bedding will need to be excavated and voids backfilled with bedding material. The subgrade foundation soils must be composed of stiff to hard in-situ soil, stabilized soil, or compacted fill.

A. Soft Soils

Where poor or soft soils are encountered, consideration should be given to removing some or all of the poor material and replacing it with compacted underwater backfill material. A separation geotextile may be required to prevent migration and mixing of the compacted underwater backfill with the underlying poor soils.

The bearing capacity of soft foundation soils may be improved with the use of a reinforcement/separation geotextile. Furthermore, the structural backfill soil envelope should not be allowed to settle more than the box, in order to avoid potential downdrag loads on the sidewalls. Therefore, the layer of reinforcement geotextile should extend at least 1 foot beyond the footprint of the box. Uniform settlement along the length of the box is desirable.

B. Soil Envelope

The lateral limit of the soil envelope is a minimum of 3 feet wide at the footing and should extend upward to the road surface elevation. Backfill requirements should be supplied by the Geotechnical Designer for inclusion in the contract documents.

Structures backfilled with flowable fill must be guarded against flotation.

8.3.3 Concrete Box Culverts

Concrete boxes can be precast or cast-in-place. If precast is chosen, standard sizes should be used whenever possible to save cost. However, non-standard sizes can be fabricated when needed. When using a non-standard size, the manufacturer should be contacted to be sure the sections are not too big or heavy to be transported to the site and erected.

Precast concrete boxes are detailed on contract plans with only the basic layout and required hydraulic opening, so that the Contractor can choose among available proprietary products. The manufacturer is responsible for the design of the structure, which includes determination of wall thickness, haunch thickness, and reinforcement. The loading specified for the structure should be HS25 and Special Provision 534 must be included in the PS&E package. Soil type 4 should be used in the design of earth loads from the soil envelope (refer to Section 3.6 Earth Loads).

Table 8-6 is based on ASTM C789. The waterway area is reduced to account for an assumed 10 inch haunch at each corner. The actual dimension of the haunch may vary slightly among manufacturers.

Table 8-6 Precast Concrete Box Sizes

Span (ft)	Rise (ft)	Waterway Area (ft^2) Single box	Waterway Area (ft^2) Twin boxes
8’	6’	46.6	93.2
8’	7’	54.6	109.2
8’	8’	62.6	125.2
9’	6’	52.6	105.2
9’	7’	61.6	123.2
9’	8’	70.6	141.2
9’	9’	79.6	159.2
10’	6’	58.6	117.2
10’	7’	68.6	137.2
10’	8’	78.6	157.2
10’	9’	88.6	177.2
10’	10’	98.6	197.2
11’	6’	64.6	129.2
11’	8’	86.6	173.2
11’	9’	97.6	195.2
11’	10’	108.6	217.2
11’	11’	119.6	239.2
12’	8’	94.6	189.2
12’	10’	118.6	237.2
12’	12’	142.6	285.2

8.4 Three-Sided Structures and Arches

8.4.1 Design

A three-sided structure or arch may be preferred for those projects where the integrity of the stream bottom must be maintained. These can be concrete rigid frames, concrete arches, or metal arches. Metal arches may be steel or aluminum structural plate.

For all these structures, the footings are designed by the Structural Designer. Refer to Section 5.3 Spread Footings for the design guidelines. For those buried structures on footings, the springing line should be located at or above Q1.1 for ease of construction and longevity.

8.4.2 Metal Arches

The minimum cover is equal to the span divided by 8 or 1'-6" minimum, whichever is greater. The minimum cover should be checked at the face of guardrail from the top of the bituminous pavement. The lateral limit of the soil envelope is 3 feet wide at the footing and extends upward to the subgrade elevation. Backfill requirements should be supplied by the Geotechnical Designer for inclusion in the contract documents.

The plate thickness for arch structures should be specified in the contract documents as shown in the tables in Section 8.4.2.1. If reinforcing ribs are required for the structure, they should be designed by the manufacturer. The thickness of the plates to be used for design should be the thickness stated on the plans minus 0.055 inches or 0.060 inches for aluminum or steel structures, respectively. Refer to Appendix D Standard Notes Structural Plate Structures.

8.4.2.1 Structural Plate Arch Tables

For metal structural plate arches, tables were developed in the same manner as those described in Section 8.2.4 Structural Plate Pipes and Pipe Arches Design Tables Commentary.

Table 8-7 Steel Structural Plate Arches

Span (in)	Min. Cover (ft)	Maximum Fill Height Above Top of Arch (feet) Metal Thickness in inches					
		0.138 in	0.168 in	0.188 in	0.218 in	0.249 in	0.280 in
72	1.5	18	30	30	30	30	30
84	1.5	16	30	30	30	30	30
96	1.5	14	25	30	30	30	30
108	1.5	12	20	25	30	30	30
120	1.5	11	20	25	30	30	30
132	1.5	9	18	20	25	30	30
144	1.5	8	16	20	25	30	30
156	1.6	7	16	18	20	25	30
168	1.8	6	14	16	20	25	25
180	1.9	6	12	16	20	20	25
192	2.0	5	12	14	18	20	25
204	2.1		11	12	16	20	20
216	2.3		9	11	14	18	20
228	2.4		8	10	12	16	18
240	2.5			8	11	14	16
252	2.6			7	9	12	14
264	2.8				8	10	12
276	2.9				7	9	10
288	3.0					7	9
300	3.1					6	8

Table 8-8 Aluminum Structural Plate Arches

Span (in)	Min. Cover (ft)	Maximum Fill Height Above Top of Arch (feet) Metal Thickness in inches				
		0.150 in	0.175 in	0.200 in	0.225 in	0.250 in
60	1.5	25	30	30	30	30
72	1.5	20	25	30	30	30
84	1.5	18	20	25	30	30
96	1.5	16	20	20	25	30
108	1.5	14	18	20	25	25
120	1.5	12	16	18	20	25
132	1.5	11	14	16	20	20
144	1.5	9	12	16	18	20
156	1.6	9	11	14	16	20
168	1.8	8	10	14	16	18
180	1.9	7	9	12	14	16
192	2.0	6	8	10	12	14
204	2.1	5	6	8	10	12
216	2.3	4	5	7	9	10
228	2.4		4	6	7	8
240	2.5		3	5	6	7
252	2.6			4	5	6
264	2.8			3	4	5
276	2.9				3	4

8.4.2.2 End Treatment

A. Steel Structural Plate Arches

The end treatment should be the same as required for steel structural plate pipes and pipe arches. In addition, a top step cut should be provided with a height of about 12 inches.

B. Aluminum Structural Plate Arches

The end skew and bevel, bottom step cut, and end reinforcement should be the same as required for aluminum structural plate pipes and pipe arches, except the top step cut should be increased to about 12 inches whenever it is required.

8.4.3 Concrete Rigid Frames and Arches

These structures consist of both proprietary and non-proprietary systems. There is currently no MaineDOT approved list of proprietary systems. Refer to the buried structures technical resource people for the list of acceptable systems.

Precast concrete boxes are detailed on contract plans with only the basic layout and required hydraulic opening, so the Contractor can choose among available proprietary products. The manufacturer is responsible for the design of the structure, including determination of wall thickness and reinforcement. The loading specified for the structure should be HS25 and Special Provision 534 must be included in the PS&E package. If wingwalls are required, refer to Section 5.6.5 Prefabricated Proprietary Walls. In general, a concrete modular wall system is preferred for more extensive walls due to increased longevity.

Spread footing loads should consider all reactions transferred to the footings through the arch walls. A minimum backfill compaction to prevent roadway settlement adjacent to the structure should be provided by the Geotechnical Designer for inclusion in the contract documents. A higher backfill compaction density may be required on structures requiring resistance to large horizontal reactions at the base of the arch wall.

The minimum cover is 6 inches. Whenever possible, the structure should be buried deep enough so that no special treatment is needed for the guardrail posts.

References

AASHTO, 1977 and Interims, *Standard Specifications for Highway Bridges*, Washington, DC